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Title: Improving students' problem solving in a virtual chemistry simulation through metacognitive messages

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Abstract Body

Limit 4 pages single spaced.

Background / Context:

Description of prior research and its intellectual context.

Recent assessments indicate that American students do not score well on tests of scientific problem solving, relative to students in other nations. IMMEX is a web-based virtual environment that provides students with opportunities to solve science problems by viewing information resources through a suite of menu options, developing a hypothesis and submitting the hypothesis for feedback. Students' patterns of search through the information sources are automatically classified by the IMMEX software using Hidden Markov Models, producing a quantitative measure of strategic efficiency. Prior work has found that many students do not use effective strategies in IMMEX and that they tend to retain poor strategies over time (Stevens, Beal & Sprang, 2009). That is, practice alone does not lead to better problem solving.

Purpose / Objective / Research Question / Focus of Study:

Description of the focus of the research.

The goal of the study was to learn if students' problem solving could be improved through the addition of metacognitive messages into the IMMEX simulation for chemistry. Prior work on the techniques used by effective human tutors indicates that they discuss how to approach a problem, how to monitor one's progress and how to manage information resources effectively while solving a problem. The study question was whether messages based on a model of effective human tutoring could be integrated into the simulation and improve students' strategic effectiveness.

Setting:

Description of the research location.

The study was conducted in chemistry classes in a large Southern California school district in which IMMEX is part of the science curriculum. The district serves a diverse student population (35% Hispanic, 48% White, 15% Asian American, 2% African American). Science teachers receive professional development training in integrating IMMEX into their classes (Thadani, Stevens & Tao, 2009). Teachers set up student accounts in IMMEX and are free to use it whenever they want to during the academic year. Most teachers schedule 6-8 sessions over the course of the academic year.

Population / Participants / Subjects:

Description of the participants in the study: who, how many, key features, or characteristics.

The study included Grade 9 students in chemistry classes who participated as part of their classroom work. The sample used in the analyses included students who completed at least five cases in the Duck Run problem set. There were 195 students who used the message-enhanced

version of IMMEX, and 173 students who used the original version. (Students were randomly assigned by the server at the time of log in to one of the two versions.)

Intervention / Program / Practice:

Description of the intervention, program, or practice, including details of administration and duration. For Track 2, this may include the development and validation of a measurement instrument.

Students worked either with a version of IMMEX that included metacognitive messages delivered at the start of each case, or with the original version that did not include the messages. In the message-enhanced version, a brief text message was shown on the screen at the start of each problem in the set. Messages were delivered randomly across students, with the restriction that each message would be shown only once to an individual.

Examples of messages included: "When you work on a hard problem, sometimes you're going to feel confused. That's a sign your brain is trying out different ideas. Don't give up too soon on this case." AND "If you get confused on this case, ask yourself, 'What do I need to know to make progress, and where can I find that information?' It's fine to ask for help, but make sure you know exactly what you need help with." The messages focused on strategies for problem solving rather than on specific chemistry content.

In the study, students worked with the “Duck Run” problem set in which the objective is to use available information to identify an unknown substance for proper removal. Information sources include state of matter (solid, liquid, gas), reports from observers about characteristics, results of chemical tests performed on the substance, number of electrons, etc. Students can view the information sources in any order and have up to two tries to answer correctly. The Duck Run problem set includes 12 different versions (cases) with different unknowns and associated information sources. Cases vary in difficulty and are delivered in random order. Each case takes approximately 15 to solve on average.

Research Design:

A between-subjects design was used: Students used either the original version of IMMEX as part of their chemistry coursework, or a version that included metacognitive messages.

Data Collection and Analysis:

Description of the methods for collecting and analyzing data.

As students solved cases in IMMEX, their actions, including selection of information sources to view, the order in which different sources of information were viewed, and the time taken on the case were automatically recorded, along with the problem outcome (correct on the first or second attempt, or not correct). A Hidden Markov Model is used to classify the student’s strategic efficiency on each case. The Strategic Efficiency Index is a quantitative measure of the extent to which the student views the appropriate information sources, does not return to view information that has already been seen, and whether the correct answer is chosen in one or two attempts (or not at all). The SEI metric is automatically computed by the IMMEX software. Data for each student included the SEI score on each case, as well as answer accuracy.

Findings / Results:

Description of the main findings with specific details.

Results indicated that there were no differences in initial performance in IMMEX, meaning that the two groups scored similarly on the first case. However, students who worked with the message-enhanced version showed more improvement across cases, meaning that they became more efficient in their problem solving, as well as more likely to find the correct solution. The differences between the groups were most apparent on the most difficult cases (difficulty was established in prior research with IMMEX). Additional analyses focused on the performance of students in both groups who continued to use inefficient problem solving strategies, such as looking through information sources haphazardly, consulting information not relevant to the current case, and looking at the same information multiple times. On the fourth and fifth cases, there were relatively few students who continued to use poor strategies but those who were in the message-enhanced IMMEX group were more likely to solve the cases correctly. This suggested the possibility that the messages promoted better integration of the information even among students with the weakest skills.

Conclusions:

Description of conclusions, recommendations, and limitations based on findings.

The findings suggest that students can be assisted to adopt better problem solving strategies through relatively simple changes to a technology-based learning environment. The addition of messages designed to encourage students to think about their actions, set goals and monitor progress, engage in appropriate help-seeking and tolerate a certain amount of frustration during problem solving appeared to be beneficial, especially for students who were not doing particularly well in the activity.

Appendices

Not included in page count.

Appendix A. References

References are to be in APA version 6 format.

Beal, C. R., & Stevens, R. H. (2011). Improving students' problem solving in a web-based chemistry simulation through embedded pedagogical messages. *Technology, Instruction, Cognition and Learning*, in press.

Stevens, R., Beal, C. R., & Sprang, M. (2009, Dec.). *Tracking the development of problem solving skills with learning trajectories.* In S. C. Kong et al. (Eds.), Proceedings of the 17th International Conferences on Computers in Education, pp. 99-106. Hong Kong: Asia Pacific Society for Computers in Education.

Thadani, V., Stevens, R. H., & Tao, A. (2009). Measuring complex features of science instruction: Developing tools to investigate the link between teaching and learning. *Journal of the Learning Sciences*, *18*, 285-322.